

Improvement of Phosphate Adsorption Kinetics onto Ferric Hydroxide by Size Reduction

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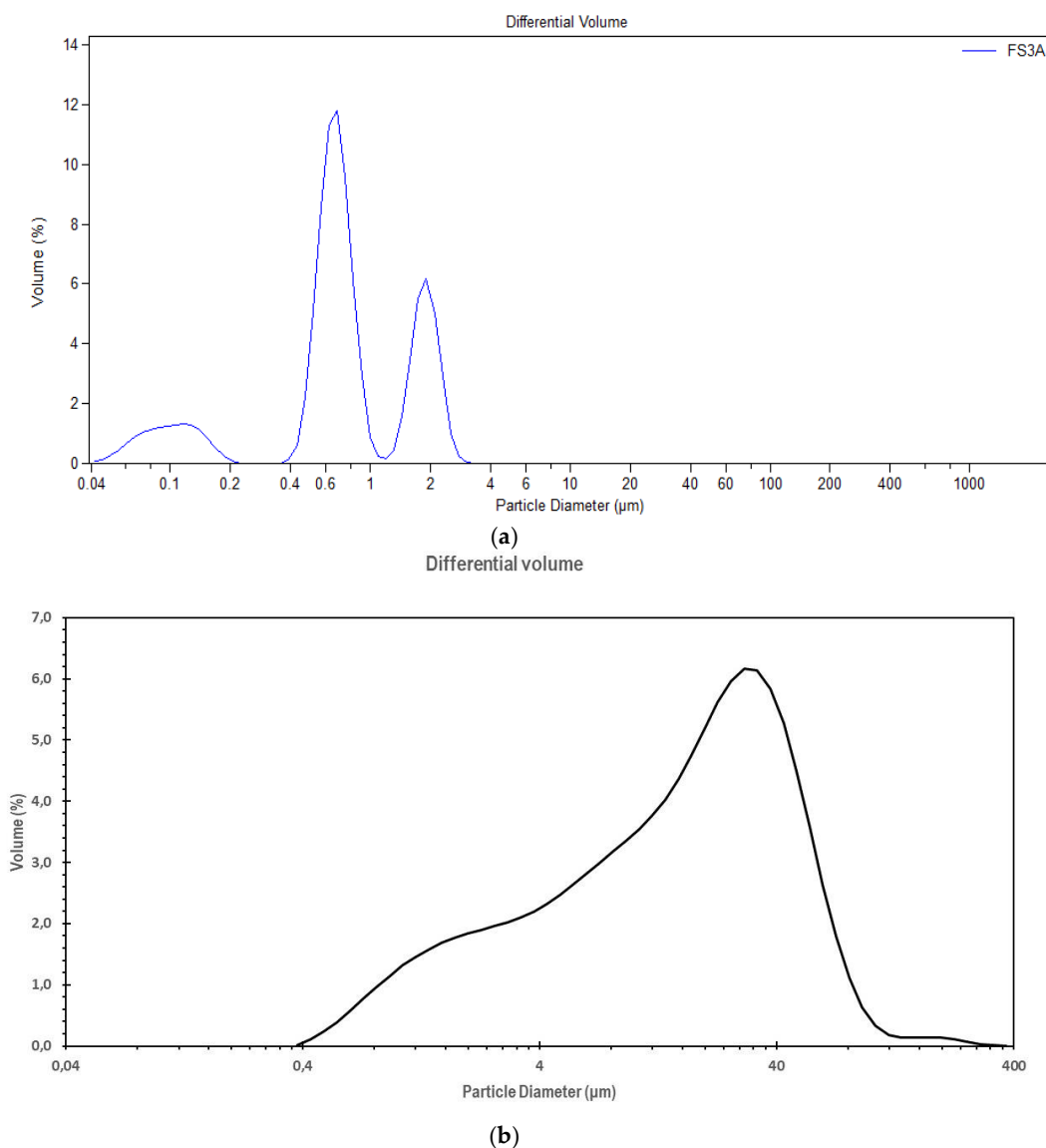
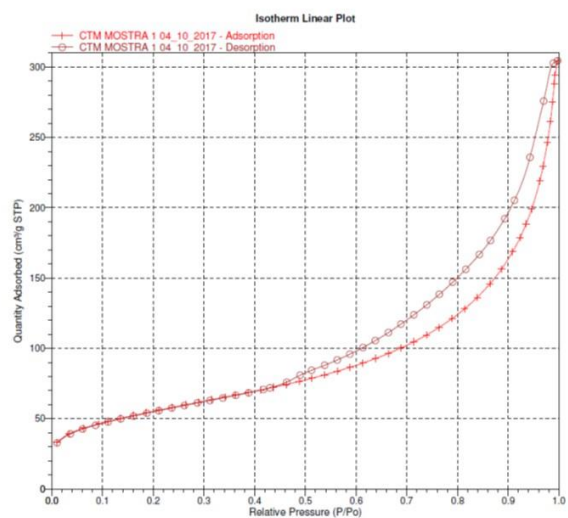
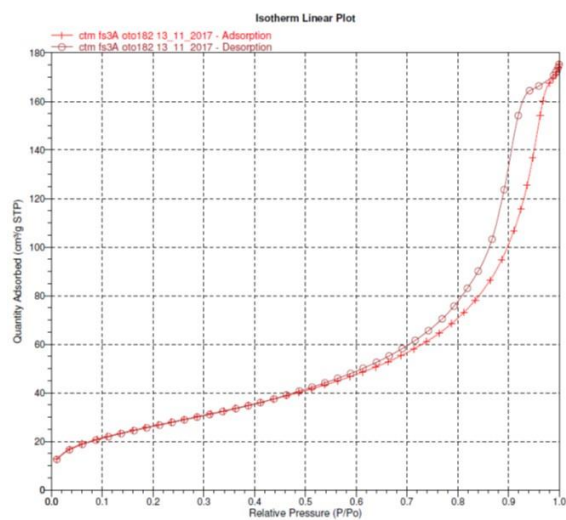


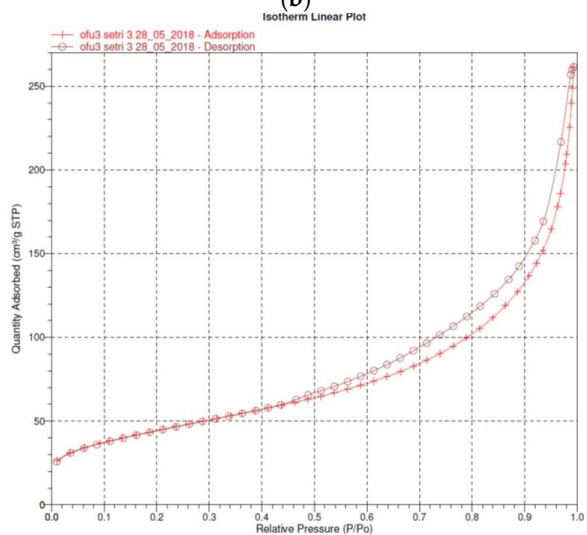
Figure S1. Size distribution (a) OF-M (milled), (b) OF-U (ultra-sonicated).



(a)



(b)



(c)

Figure S2. BET curves (a) GFH, (b) OF-M (milled), (c) OF-U (ultra-sonicated).

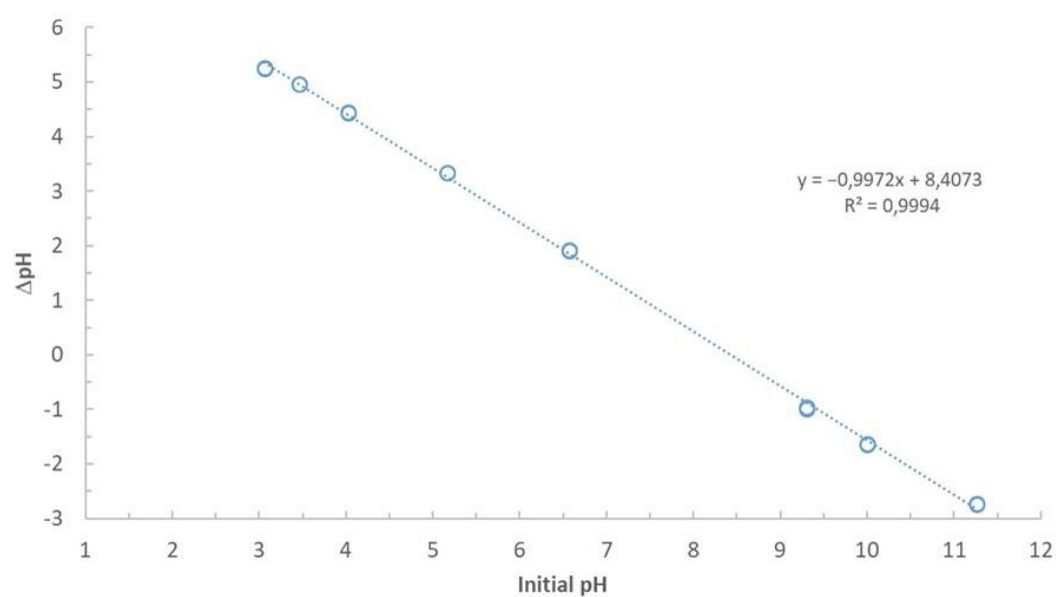
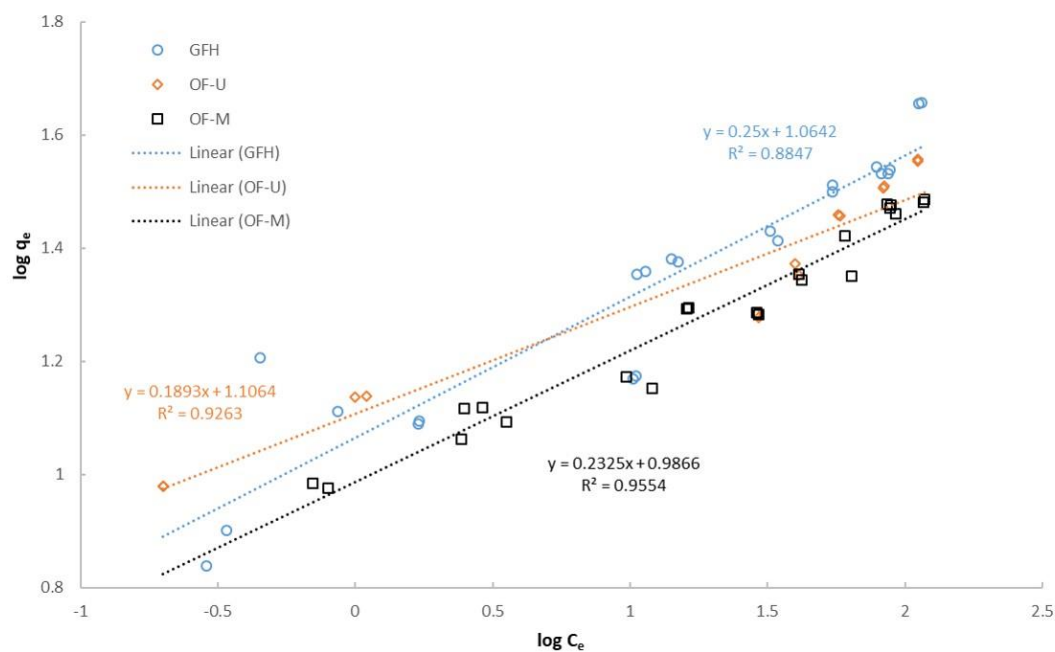
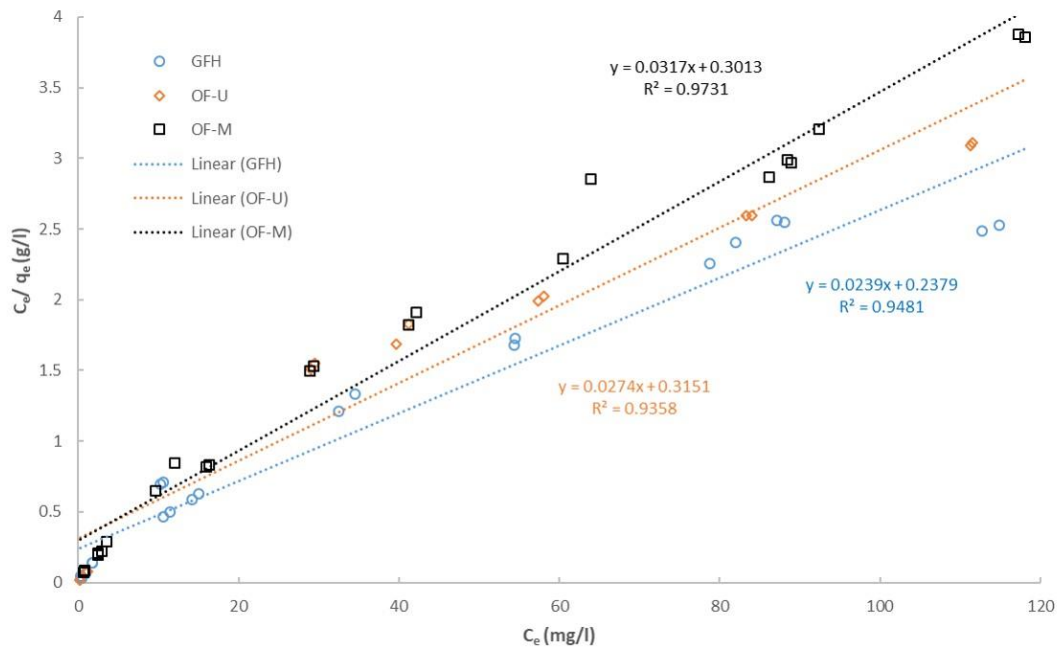


Figure S3. Regression fitting for the calculation of pH_{PZC} (FGH).



(a)



(b)

Figure S4. Linear regression fittings for the equilibrium models (a) Freundlich model, (b) Langmuir model.

Table S1. 95% significance test for b_3 in Langmuir fitting parameters (a) Comparison GFH ($D = 0$) and OF-M ($D = 1$), (b) Comparison GFH ($D = 0$) and OF-U ($D = 1$).

SUMMARY OUTPUT

GFH vs OF-M

Regression Statistics	
Multiple R	0.982760897
R Square	0.965818982
Adjusted R Square	0.963255405
Standard Error	0.222550143
Observations	44

ANOVA

	df	SS	MS	F	Significance F
Regression	3	55.9791738	18.6597246	376.7467161	2.39604E-29
Residual	40	1.981142641	0.049528566		
Total	43	57.96031644			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.237905653	0.065762378	3.617655864	0.000824554	0.104994929	0.370816377
Ce	0.02392523	0.00122661	19.50516999	4.84956E-22	0.021446159	0.0264043
D	0.063369259	0.095530174	0.663342861	0.510916092	-0.129704425	0.256442943
D-Ce	0.007726479	0.001717495	4.498690812	5.75792E-05	0.004255292	0.011197666

Significant difference of slopes (q_{max})

(a)

SUMMARY OUTPUT

GFH vs OF-U

Regression Statistics	
Multiple R	0.972227164
R Square	0.945225659
Adjusted R Square	0.940090565
Standard Error	0.255705097
Observations	36

ANOVA

	df	SS	MS	F	Significance F
Regression	3	36.10664124	12.03554708	184.0717182	2.95275E-20
Residual	32	2.092323092	0.065385097		
Total	35	38.19896433			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.237905653	0.07555949	3.148587331	0.003541433	0.083996008	0.391815298
Ce	0.02392523	0.001409347	16.97611199	1.4566E-17	0.021054484	0.026795975
D	0.077199973	0.131123538	0.588757553	0.56015728	-0.189889933	0.34428988
D-Ce	0.003523407	0.002274152	1.549327347	0.131137603	-0.00110889	0.008155703

Not significant difference of slopes (q_{\max})

(b)

Table S2. Adsorption of main anions in wastewater.

Initial conditions				Anions ¹	
Sample	t (h)	m/V (g/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulphate (mg/L)
MR-1 ²	0	0	796.5	25.0	61.5
MR-1	120	2	798.0	25.0	99.5
MR-1	120	3	797.5	25.0	116.0
MR-2 ²	0	0	392.5	101.6	320.0
MR-2	120	2	393.0	106.7	362.0
MR-2	120	3	390.0	106.7	379.5

¹ Average of two values ² Initial values**Theoretical phosphate removal**

The theoretical determination of the phosphate removal as a function of the initial concentration and adsorbent dosage is shown in Figure S5. The figure was calculated from the equilibrium concentration of the FGHI isotherm using Equations (1), (2), and (4), coded into Microsoft Excel™ spreadsheet.

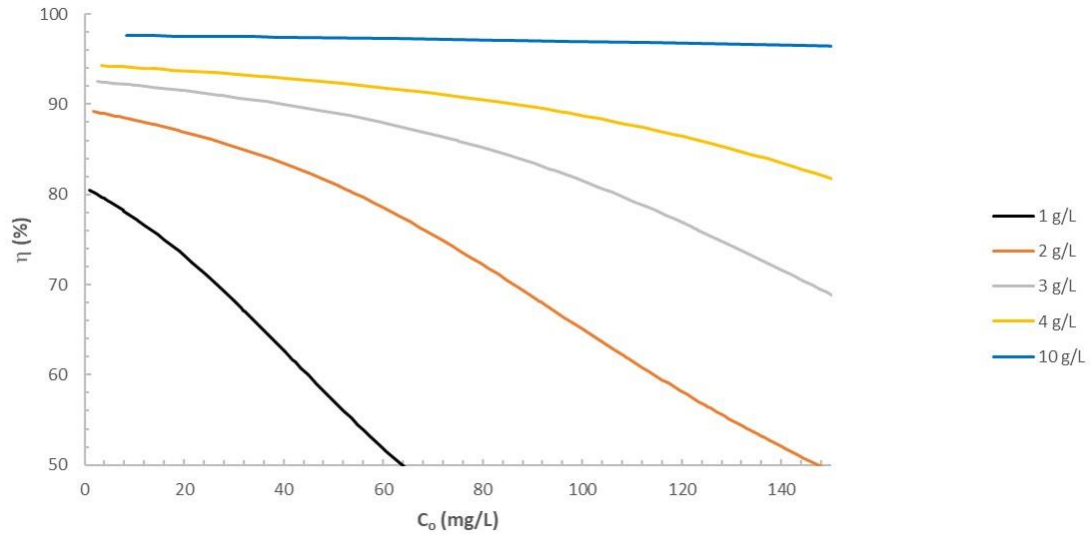
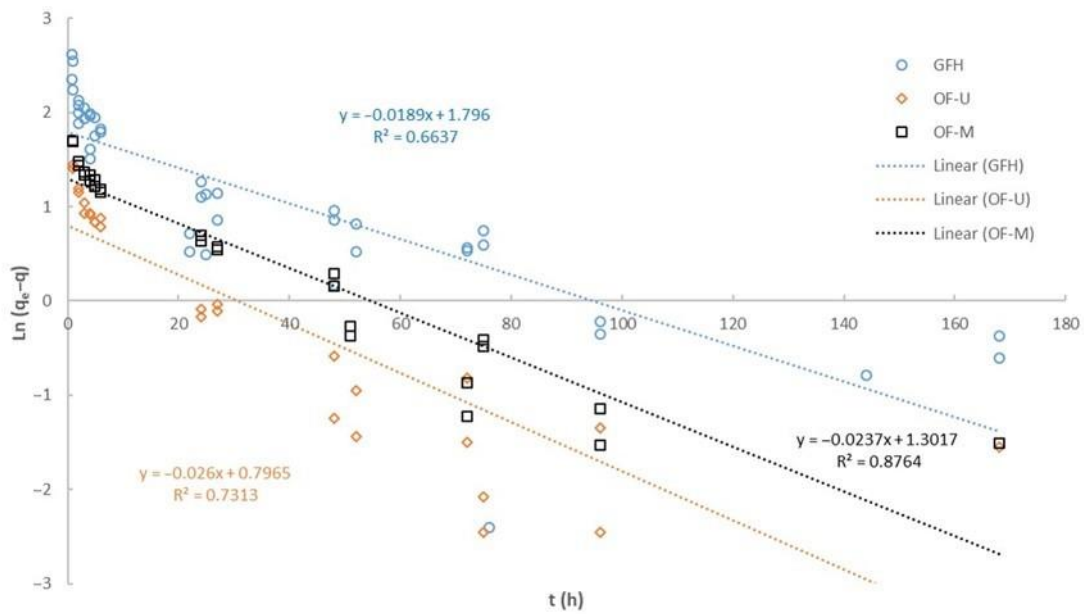
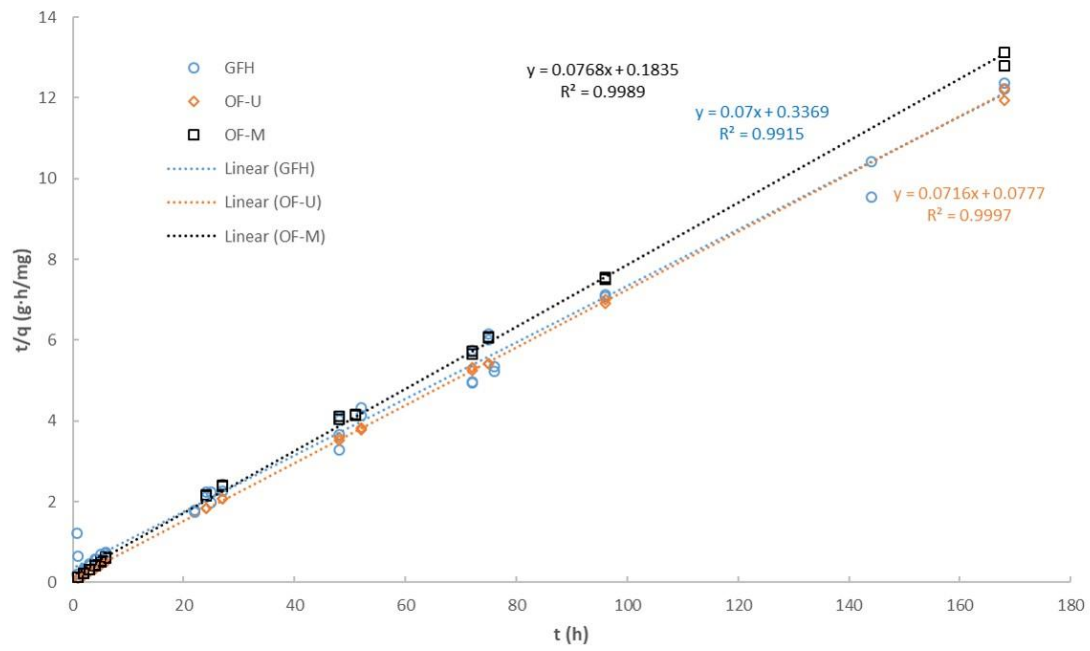


Figure S5. Theoretical phosphate removal from Langmuir isotherms (GFH) as a function of initial phosphate concentration and adsorbent concentration (dosage).

These results could be used to optimize the removal and the adsorbent dose for samples with different concentrations of phosphates. For example, with an initial concentration of 40 mg/L of phosphate (similar to MR-2 wastewater), a dosage of 3 g/L would be needed to reach 90% removal. For higher removal values, the dosage would need to be increased which also increases the operational costs, but recovery becomes less sensitive to initial concentration.



(a)



(b)

Figure S6. Linear regression fittings for the kinetic models (a) Pseudo first-order model, (b) Pseudo second-order model.

Table S3. 95% significance test for b_3 in second-order fitting parameters, (a) Comparison GFH ($D = 0$) and OF-M ($D = 1$), (b) Comparison GFH ($D = 0$) and OF-U ($D = 1$).

SUMMARY OUTPUT

GFH vs OF-M

Regression Statistics	
Multiple R	0.997332872
R Square	0.994672857
Adjusted R Square	0.994444551
Standard Error	0.252318409
Observations	74

ANOVA

	df	SS	MS	F	Significance F
Regression	3	832.1120654	277.3706885	4356.750496	1.8E-79
Residual	70	4.456520568	0.06366458		
Total	73	836.568586			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.336881149	0.05072021	6.641950969	5.57799E-09	0.23572288	0.438039418
t	0.070022607	0.0008118	86.25599967	8.14054E-73	0.068403523	0.071641691
D	-0.153362609	0.081599868	-1.87944678	0.064346262	-0.316108415	0.009383196
D·t	0.00680702	0.001306779	5.209006572	1.82327E-06	0.004200732	0.009413309

Significant difference of slopes (qe)

(a)

SUMMARY OUTPUT

GFH vs OF-U

<i>Regression Statistics</i>	
Multiple R	0.997368089
R Square	0.994743106
Adjusted R Square	0.99451781
Standard Error	0.243664403
Observations	74

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	786.4369422	262.1456474	4415.282288	1.13112E-79
Residual	70	4.156063898	0.059372341		
Total	73	790.5930061			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	0.336881149	0.048980611	6.877847068	2.08405E-09	0.239192401	0.434569897
t	0.070022607	0.000783957	89.31947515	7.22929E-74	0.068459055	0.07158616
D	-0.25920569	0.078831027	-3.288117616	0.00157977	-0.416429217	-0.101982163
D:t	0.00160459	0.001261707	1.271761641	0.207666917	-0.000911804	0.004120985

No significant difference of slopes (qe)

(b)